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ABSTRACT

Strategies used by 15 fifth and sixth grade students to comprehend written problem solving tasks were identified. A naturalistic protocol analysis procedure was used to gather and analyze students' verbal and written responses to 55 selected reading and thinking tasks. In the ten tasks selected for detailed analysis, students demonstrated marked differences in their use of four principal strategies: visualization, experimentation, abstraction, and extension. Analysis of incorrect responses generated three principal categories of errors: "perplexed responses," "literally bound responses," and "attempted experimentation." The results of this investigation provide further description of the process of transition from concrete to formal operations occurring during early adolescence and suggest implications for curricular planning and reading instruction for middle school students. (Author/BW)

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An Observational Analysis of Performances on Reading and Thinking Tasks of Early Adolescents

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Abstract

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on Reading and Thinking Tasks of Early Adolescents

Identified strategies used by 15 fifth and sixth grade students to comprehend written problem solving tasks. A naturalistic protocol analysis procedure was used to gather and analyze students' verbal and written responses to 55 selected reading and thinking tasks. In the ten tasks selected for detailed analysis, students demonstrated marked differences in their use of four principal strategies: visualization, experimentation, abstraction, and extension. Analysis of incorrect responses generated three principal categories of errors: "perplexed responses," "literally bound responses," and "attempted experimentation."

The results of this investigation provide further description of the process of transition from concrete to formal operations occurring during early adolescence and suggest implications for curricular planning and reading instruction for middle school students.

An Observational Analysis of Performances

on Reading and Thinking Tasks of Early Adolescents

During the middle school years, students undergo a number of developmental changes. Among the most critical of these changes are maturations in cognitive processes. During the age range from 11 through 14 years, the early adolescent more consistently performs concrete operations and begins to demonstrate more abstract thinking abilities (Piaget, 1970). The wide range of individual differences in both the scope and rate of this cognitive development has important implications for middle school educators. Two ways classroom teachers can learn more about the cognitive development of their students are to listen to their verbal comments while discussing problem solving tasks and to analyze their written responses to such tasks. This study is an attempt to more fully describe some of the ways early adolescents respond to reading and thinking tasks and to do so in a naturalistic manner. The specific purposes of this study are to compare the performances of fifteen randomly selected fifth and sixth grade students on tasks combining problem solving and reading, to describe the problem solving strategies used on such tasks, and to analyze correct and incorrect responses to the problem.

Theoretical Framework

A wide range of studies suggest an essential relationship between the acquisition of more sophisticated thinking abilities as evidenced by Piagetian problem solving tasks and reading achievement. In reviewing a number of such studies, Waller (1977) suggests that concrete operations are essential prerequisites for fluent reading and formal operations are essential prerequisites for mature reading comprehension. He concludes that "mature reading comprehension is likely not possible without the ability to think operatively about written propositions in the abstract, i.e., without the competencies underlying formal operations" (p.7). To explore some of the relationships between concrete operations and reading, Malone (1975) administered Piagetian task test items and the reading subtests of the Comprehensive Tests of Basic Skills to 138 sixth and seventh grade students. Using a series of stratified random grouping procedures, she found that even when the effects of sex, age, grade level placement, and language ability were held constant, scores on concrete operational tasks correlated significantly with reading achievement scores. In further exploring the relationships between more formal operations and reading, Lawson, Norland and Kahle (1975) administered Piagetian interviews to 35 students in grades nine through twelve. They found correlations of .58 to .75 with formal tasks and scores on the Sequential Tests of Education Progress reading tests.

While such evidence suggests that students who think more sophisticatedly are better readers, such studies do not provide insights into the ways students think in response to specific reading and thinking tasks. Recent investigations of reading comprehension suggest that

protocol analysis techniques have great potential for describing thinking strategies used by readers in responding to selected reading passages.

Fareed (1971) defines "protocols" as "the verbatim records of the readers complete verbalizations during the experimental situations, the transcripts of which were typed after recording by means of a tape recorder" (p.498). Olshavsky (1977) notes that "protocol analysis, as used in cognitive psychology to study problem solving behavior, requires a subject to think aloud as he solves a problem" (p.661). She adapted the procedure to study reading strategies by requiring subjects to read clauses of a short story and then "think aloud" using a tape recorder. She further suggests that such a method is an excellent process for describing strategy usage because the subjects report behavior; there is little delay between reading and reporting; recordings transcribe ongoing behavior; and the data can be analyzed by researchers for evidence of strategies (p.662). In her analysis of the protocols of 24 tenth grade students, she identified ten different comprehension strategies. She used the term "strategy" to denote a purposeful means of comprehending and emphasized the subjects' use of recurring thought processes, or "operations" in generating strategy descriptors. She found strategy usage related to interest, proficiency, and writing style. Kavale and Schreiner (1979) used this same protocol analysis procedure to identify and compare the reasoning strategies used by good and poor readers in responding to standardized measures of reading comprehension. The efficacy of these investigations in generating descriptions of strategies suggest that protocol analysis procedures might also provide insights into students' strategy usage in reading and problem solving tasks.

In an earlier phase of this research project, the investigator (Strahan, 1980) used a modified protocol analysis procedure and found that early adolescents who were in a "transitional" stage between concrete and formal operations used four primary problem solving strategies in performing reading and thinking tasks: visualization, experimentation, abstraction, and extension (see Appendix A). This study seeks to further explore these problem solving strategies in analyzing performances by students in varying stages of cognitive development.

Research Methods

In January 1980, the 73 fifth and sixth grade students at Holcomb Campus School were given the Concrete-Operational Reasoning Test. Fifteen students were selected at random to be the subjects of this study. These fifteen students were divided into four groups on the basis of their scores on the Concrete-Operational Reasoning Test (Ankeney and Joyce, 1974). As reported in Table I, scores ranged from 6 to 28 on the 30 item test. The author and three graduate students composed the research team for gathering observational data. Using materials from Thinklab (SRA, 1974), Inductive Thinking Skills (Harnadek, 1977), and Interview Activities (Sund, 1976), the author compiled a schedule of

problem solving activities incorporating tasks in both concrete and formal operations (see Appendix B). The four groups of students then met with a researcher for seven sessions to complete the problem solving tasks. During each forty-five minute session, the research team member acted as facilitator, giving directions, encouraging students to talk about the problems, and recording all comments on cassette tapes. Whenever possible, the researchers tried to encourage students to verbalize their thought processes, asking questions such as "how did you figure that out?" "what were you thinking?" and "what is going through your mind as you try to solve this problem?" During April and May the research team began analyzing the recorded data, categorizing responses according to the appropriate concrete or formal operation involved. The author then began to synthesize data and to generate descriptors for recurring patterns of behaviors among the transitional students. These patterns were tested in re-analysis of the recorded data and emerged as "problem solving strategies" (Strahan, 1980). The recorded data was then analyzed for all fifteen students. Ten specific problem solving tasks were selected as the basis for comparisons. These ten problems represent ten different dimensions of formal operations (see Appendix B). Complete protocols were transcribed for each student on each of the ten tasks and these protocols analyzed. All fully "correct" responses were analyzed for evidence of strategy usage. All "partially correct" or incorrect responses were analyzed for types of errors and descriptors generated to describe responses.

To investigate the degree to which the resulting descriptions of the responses of these fifteen students could be used to describe the responses of a larger sample of other fifth and sixth grade students, the descriptors generated in the analysis of these protocols were tested in the analysis of 94 written protocols gathered from a sample of 35 different students. Teams of undergraduate teacher education students rated these 94 written protocols and frequency totals were compiled.

Data Sources

For this investigation, protocol analysis methodologies described earlier were modified to incorporate the analysis of student responses gathered naturalistically. Since one of the goals of this investigation was to gather data that parallels classroom information readily available to teachers, the researcher decided to obtain protocols from student responses on written tasks and in informal discussions. Such responses may well be more naturalistic as classroom teachers rarely have an opportunity to interview students individually or to obtain highly structured, individualized protocols such as those used in more formal protocol analysis procedures (Olshavsky, 1977; Kavale and Schreiner, 1979). For this investigation, researchers sometimes encouraged students to discuss problems in groups, recording all comments and later transcribing individual responses and assessing individual roles in group solutions. Researchers also encouraged students to continue exploring solutions, sometimes in

groups, sometimes individually. Researchers also encouraged students to write down their thoughts. Such procedures approximate classroom conditions.

Students' oral and written comments in response to the ten selected tasks served as protocols for the generation of descriptors. Oral responses were transcribed into written protocols and all protocols were then organized by student and task. The research team then analyzed each protocol for "correctness" of response. In instances where there were more than one correct solution, responses were judged "correct" or "incorrect" on the basis of their appropriateness to the task.

The written responses of 35 different students to five different problem solving tasks served as the protocols for the analysis of the generalizability of the descriptors generated. The five problem solving tasks selected parallel the dimensions of formal operations of the original ten tasks and could be answered in written format (see Appendix C).

To assess the reliability of the descriptors generated, the investigators asked two independent analysts to individually classify 30 of these written protocols using the definitions in Appendix A, both analysts professors of reading education familiar with protocol analysis procedures. Coefficients of inter-rater reliability were then computed for both analysts and the investigator using a formula for estimating the degree of agreement (Squire, 1964). A resulting coefficient of agreement of .7666 compared equitably with those reported in other studies (Squire, 1964; Olshavsky, 1977; Kavale and Schreiner, 1979). It was concluded that the classification scheme was adequately reliable for categorizing subjects' written responses.

Undergraduate teacher education students read all 94 protocols and categorized them according to the descriptors and definitions generated (Appendix A). Each protocol was read and rated independently by three different raters. These ratings were then subjected to frequency compilations.

Results

The results of the analysis of student responses on the ten original problem solving and reading tasks demonstrate a wide range of individual differences in problem solving abilities and suggest two principal insights about the use of problem solving strategies:

1. In their correct responses, all fifteen students demonstrated at least some use of the four principal problem solving strategies described in an earlier phase of this research.

2. Three principal categories characterize most of the errors these fifteen students made on these ten tasks: perplexed responses, literally bound responses, and attempted experimentation.

Table 1: Scores on Concrete-Operational Reasoning Test and Ten Problem Solving Tasks by Group

			Concrete-operational Reasoning Test (30 possible)	Ten Problem Solving Tasks
Group One	Student	A	6	1
		B	12	1
		C	15	4
	Group Average		11.0 (36.6%)	2.0
Group Two	Student	D	17	4
		E	17	5
		F	18	4
		G	18	4
	Group Average		17.5 (58.3%)	4.25
Group Three	Student	H	19	5
		I	21	5
		J	24	4
		K	24	7
	Group Average		22.0 (73.3%)	5.25
Group Four	Student	L	25	8
		M	25	9
		N	26	9
		O	28	9
	Group Average		26.0 (87.5%)	8.75

Analysis of original protocols

The scores reported in Table I demonstrate marked differences between the four groups in problem solving performances. Originally grouped on the basis of Concrete-Operational Reasoning Test scores, students demonstrated a similar progression on the problem solving tasks. Scores ranged from 6 of 30 on the Concrete-Operational Reasoning Test and 1 of 10 problem solving tasks for student A to 28 of 30 and 9 of 10 for student O. Average scores for all four groups on the ten problem solving tasks paralleled the progression of scores on the Concrete-Operational Reasoning Test. Again, large differences occurred in performances on the problem solving tasks. Group One averaged 2.0 problems correct and Group Four averaged 8.75.

Table II: Analysis of Correct Responses by Strategy

	Interview Tasks				Thinklab Tasks			Inductive Thinking Tasks			
	1	2	3	4	5	6	7	8	9	10	Totals
Group One											
Student A				VIS							
B				VIS							
C	EXP		EXT	VIS	ABS						
Group Two											
Student D	EXP			ABS	ABS					ABS	
E			EXT	ABS	ABS			ABS		ABS	
F		EXT			ABS			ABS		ABS	
G		VIS		ABS	ABS					ABS	
Group Three											
Student H	VIS	EXT		VIS	ABS			ABS			
I		ABS		ABS	ABS	EXP		ABS			
J		VIS		ABS	ABS					ABS	
K		VIS	EXT	VIS	ABS	EXP		ABS		ABS	
Group Four											
Student L	EXT	ABS	EXT	ABS	ABS	EXP		ABS		ABS	
M	EXP	ABS	EXT	ABS	ABS	VIS	EXP	ABS		ABS	
N	EXP	EXT	EXT	ABS	ABS	EXP	EXP	ABS		ABS	
O	ABS	ABS	EXT	ABS	ABS	EXP	EXP	ABS		ABS	
Totals	7	10	7	14	13	6	3	9	0	10	79
Totals by Category:											
Visualization	1	3	0	5	0	1	0	0	0	0	10 (12.6%)
Experimentation	4	0	0	0	0	5	3	0	0	0	12 (15.2%)
Abstraction	1	4	0	9	13	0	0	9	0	10	46 (58.2%)
Extension	1	3	7	0	0	0	0	0	0	0	11 (13.9%)

VIS - Visualization EXP - Experimentation ABS - Abstraction EXT - Extension

The analysis of correct responses by strategy (Table II) revealed differences among groups in the types of strategies used. Two of the three members of group one solved one problem correctly and used visualization strategies. Members of groups two and three used primarily one or two strategies while members of group four used three or four strategies more flexibly.

Table I: Scores on Concrete-Operational Reasoning Test and Ten Problem Solving Tasks by Group

			Concrete-operational Reasoning Test (30 possible)	Ten Problem Solving Tasks
Group One	Student	A	6	1
		B	12	1
		C	15	4
	Group Average		11.0 (36.6%)	2.0
Group Two	Student	D	17	4
		E	17	5
		F	18	4
		G	18	4
	Group Average		17.5 (58.3%)	4.25
Group Three	Student	H	19	5
		I	21	5
		J	24	4
		K	24	7
	Group Average		22.0 (73.3%)	5.25
Group Four	Student	L	25	8
		M	25	9
		N	26	9
		O	28	9
	Group Average		26.0 (87.5%)	8.75

Table II: Analysis of Correct Responses by Strategy

	Interview Tasks				Thinklab Tasks			Inductive Thinking Tasks			
	1	2	3	4	5	6	7	8	9	10	
Group One											
Student A				VIS							
B				VIS							
C	EXP		EXT	VIS	ABS						
Group Two											
Student D	EXP			ABS	ABS					ABS	
E			EXT	ABS	ABS			ABS		ABS	
F		EXT			ABS			ABS		ABS	
G		VIS		ABS	ABS					ABS	
Group Three											
Student H	VIS	EXT		VIS	ABS			ABS			
I		ABS		ABS	ABS	EXP		ABS			
J		VIS		ABS	ABS					ABS	
K		VIS	EXT	VIS	ABS	EXP		ABS		ABS	
Group Four											
Student L	EXT	ABS	EXT	ABS	ABS	EXP		ABS		ABS	
M	EXP	ABS	EXT	ABS	ABS	VIS	EXP	ABS		ABS	
N	EXP	EXT	EXT	ABS	ABS	EXP	EXP	ABS		ABS	
O	ABS	ABS	EXT	ABS	ABS	EXP	EXP	ABS		ABS	
											Totals
Totals	7	10	7	14	13	6	3	9	0	10	79
Totals by Category:											
Visualization	1	3	0	5	0	1	0	0	0	0	10 (12.6%)
Experimentation	4	0	0	0	0	5	3	0	0	0	12 (15.2%)
Abstraction	1	4	0	9	13	0	0	9	0	10	46 (58.2%)
Extension	1	3	7	0	0	0	0	0	0	0	11 (13.9%)

VIS - Visualization EXP - Experimentation ABS - Abstraction EXT - Extension

The four principal problem solving strategies generated in the description of the protocols of the four transitional students in an earlier phase of this research did fully describe the correct responses of all fifteen students on these ten tasks. All fifteen students used at least one strategy correctly and seven of the students used at least three strategies. Of the strategies themselves, students used "abstraction" far more frequently than the other three. As indicated in Table II, abstraction strategies accounted for 58.2% of the total correct responses with the other three categories accounting almost equally for the remainder.

The analysis of the incorrect responses, generated three principal categories of errors. In "perplexed responses" students indicated either confusion or lack of understanding of how to solve the problem. Sample responses included, "I don't know," "I'm not sure," or "this is too difficult." In their "perplexed responses," students demonstrated their confusion without really trying to solve the problem. In "literally bound responses," students tried to solve the problem but indicated that their thinking centered on one or two literal details or key words and thus precluded inference. For example, when asked to complete this syllogism (task 2),

> All mailmen wear purple suits.
> John is a mailman.
> Then he wears _____.

student D replied "mailmen do not wear purple suits." Student E could not accept the hypothetical situation either. When asked to describe different ways to hit a cue ball in a pool table diagram (task 3), student I replied "it's just straight lines," lining up the balls to be hit and not considering the cue ball. On task 9, all fifteen students were "literally bound." On this task, (Inferences A), students were given stories and asked to assess a list of true/false statements using three conditions--accepting the story as true, not using past knowledge, and assuming good grammar. In each case, the students could not limit themselves to the information given, insisting on using past knowledge, especially of "Jack and Jill" (p.6). "Attempted experimentation" strategies indicated students' attempts to test hypotheses and try out ideas which did not result in correct solutions. For example, when asked to determine the height of one stickman by reasoning proportionally from another (task 1), student I said, "The little ones are about two-thirds the size of the large ones so it will be three less than the other paper clip." Such responses indicate the partial use of problem solving strategies and may indicate students' progression toward formal thinking.

Table III: Analysis of Errors

	Interview Tasks				Thinklab				Inductive Thinking Skills		
	1	2	3	4	5	6	7	8	9	10	
Group One											
Student A	RG	PR	PR		PR	NR	EXP	PR	LIT	PR	
B	NR	PR	PR		NR	NR	EXP	PR	LIT	PR	
C		PR				PR	EXP	PR	LIT	PR	
Group Two											
Student D		LIT	PR			PR	EXP	EXP	LIT		
E	RG	LIT				PR	EXP		LIT		
F	NR		PR	EXP		PR	PR		LIT		
G	NR		PR			PR	PR	EXP	LIT		
Group Three											
Student H			PR			PR	PR		LIT	PR	
I	EXP		LIT				PR		LIT	PR	
J	EXP		PR			PR	PR	EXP	LIT		
K	EXP						PR		LIT		
Group Four											
Student L							EXP		LIT		
M									LIT		
N									LIT		
O									LIT		Totals
											71
Totals by Category:											
No Response	3	0	0	0	1	2	0	0	0	0	6 (8.4%)
Perplexed Response	0	3	7	0	1	7	6	3	0	5	32 (45.0%)
Random Guess	2	0	0	0	0	0	0	0	0	0	2 (2.8%)
Literally Bound Response	0	2	1	0	0	0	0	0	15	0	18 (25.3%)
Experimentation	3	0	0	1	0	0	6	3	0	0	13 (18.3%)

Errors: NR - No response
PR - Perplexed response
RG - Random guess
LIT - Literally bound response

Attempted Strategies: VIS - Visualization
EXP - Experimentation
ABS - Abstraction
EXT - Extension

Table III lists the totals for the types of errors made on these ten problem solving tasks. "Perplexed responses" accounted for 45.0% of the errors; "literally bound," for 25.3%; "attempted experimentation," for 18.3% of the errors. Two other categories, "random guessing," and "non-responses" characterized the remaining 10.6% of the responses.

Table III: Analysis of Errors

	Interview Tasks			Thinklab		Inductive Thinking Skills				
	1	2	3	4	5	6	7	8	9	10	
Group One											
Student A	RG	PR	PR		PR	NR	EXP	PR	LIT	PR	
B	NR	PR	PR		NR	NR	EXP	PR	LIT	PR	
C		PR				PR	EXP	PR	LIT	PR	
Group Two											
Student D		LIT	PR			PR	EXP	EXP	LIT		
E	RG	LIT				PR	EXP		LIT		
F	NR		PR	EXP		PR	PR		LIT		
G	NR		PR			PR	PR	EXP	LIT		
Group Three											
Student H			PR			PR	PR		LIT	PR	
I	EXP		LIT				PR		LIT	PR	
J	EXP		PR			PR	PR	EXP	LIT		
K	EXP						PR		LIT		
Group Four											
Student L							EXP		LIT		
M									LIT		
N									LIT		
O									LIT		Totals
											71
Totals by Category:											
No Response	3	0	0	0	1	2	0	0	0	0	6 (8.4%)
Perplexed Response	0	3	7	0	1	7	6	3	0	5	32 (45.0%
Random Guess	2	0	0	0	0	0	0	0	0	0	2 (2.8%)
Literally Bound Response	0	2	1	0	0	0	0	0	15	0	18 (25.3%
Experimentation	3	0	0	1	0	0	6	3	0	0	13 (18.3%

Errors: NR - No response
PR - Perplexed response
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LIT - Literally bound response

Attempted Strategies: VIS - Visualization
EXP - Experimentation
ABS - Abstraction
EXT - Extension

Table IV: Analysis of Written Protocols

Category	Absolute Frequency (Average of three raters)	Relative Frequency (Percent) (Average of three raters)	Percent of Correct Responses
Correct Responses			
Visualization	23.3	24.8%	43.1%
Experimentation	15.0	16.0%	27.8%
Abstraction	11.0	11.7%	20.3%
Extension	4.7	5.0%	8.7%
Totals - Correct	54.0	57.5%	99.9%
Errors			Percent of Errors
Perplexed Response	7.7	8.1%	19.7%
Literally Bound Responses	14.3	15.2%	36.6%
Attempted Experimentation	8.3	8.9%	21.2%
Attempted Abstraction	3.0	3.2%	7.7%
Random Guess	5.7	6.0%	14.7%
Totals - Errors	39.0	41.4%	99.9%
Other	1.0	1.1%	
Grand totals	94.0	100.0%	

Analysis of supplemental written protocols

The results of the analysis of the written responses of the thirty-five other students to five different problem solving tasks demonstrate the effectiveness of the descriptors generated in this investigation and reveal a number of differences between the original protocols and the written samples.

Of the 94 sets of three ratings on each protocol, only 16 sets showed no inter-rater agreement (17.0%). All three raters agreed 36 times (38.3%) and two of three raters agreed on the remaining 42 sets (44.7%). In rating these 94 protocols, each rater used the "other" category only one time, indicating a strong degree of generalization of these categories for other students and other protocols.

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Category	Absolute Frequency (Average of three raters)	Relative Frequency (Percent) (Average of three raters)	Percent of Correct Responses
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Totals - Correct	54.0	57.5%	99.9%
Errors			Percent of Errors
Perplexed Response	7.7	8.1%	19.7%
Literally Bound Responses	14.3	15.2%	36.6%
Attempted Experimentation	8.3	8.9%	21.2%
Attempted Abstraction	3.0	3.2%	7.7%
Random Guess	5.7	6.0%	14.7%
Totals - Errors	39.0	41.4%	99.9%
Other	1.0	1.1%	
Grand totals	94.0	100.0%	

The frequencies of category usage reported in Table IV demonstrate several differences from the frequencies reported in the analysis of the original protocols. While "abstraction" was the most commonly used strategy in the original analysis (58.2%), abstraction totaled only 20.3% of the correct responses in the analysis of written protocols. "Visualizations" rose from 12.6% to 43.1%. In the analysis of errors, "perplexed responses"

dropped from 45.0% to 19.2% and "literally bound responses" rose from 25.3% to 35.7%. These differences suggest varying responses to tasks presented orally to small groups and tasks presented in writing to individuals. "Non-responses" disappeared as a category as analysis was limited to complete written protocols which may account for some of the variation in error response frequencies (non-responses originally 8.4%).

Educational Implications

Results from the analyses of original and supplemental protocols demonstrate some of the ways early adolescents think. In response to specific reading and problem solving tasks, students demonstrate approaches that reflect their general cognitive development. Relatively high frequencies of "literally bound responses" in both the original and supplemental protocols suggests that some students have difficulties making inferences and thinking creatively, demonstrating tendencies to be "bound" by "literal" dimensions of problem solving tasks. Such behavior may be characteristic of students in a concrete operational stage. The parallel occurrence of relatively high frequencies of abstraction and visualization suggest that some students are also demonstrating very formal types of thinking and doing so within the same classrooms and grade levels.

This wide range of differences in cognitive development reinforces the importance of planning for individual differences in teaching early adolescents and of using every opportunity possible to enrich thinking skills in the classroom. The widely varying responses of the fifteen students selected at random from 73 fifth and sixth graders demonstrate the drastic differences in stages of cognitive development during this time period. The frequency of "perplexed responses" in the analysis of errors suggests that early adolescent students need encouragement to experiment with new thinking skills, to test ideas, and try out solutions in order to expand their thinking skills and reduce "literal boundedness." The fact that less than one-third of the errors made on these tasks resulted from attempted strategies suggests that teachers might well encourage the use of these strategies in classroom discussions. Findings of earlier investigations (Strahan, 1980) suggest that attempted use of problem solving strategies may indicate a transitional stage between concrete and formal operations. Since attempted strategies demonstrate growing cognitive abilities, planning thinking skills enrichment activities, demonstrating strategies, and discussing alternative solutions may help increase the use of attempted strategies and foster intellectual growth.

The results of this study also have implications for the teaching of reading in the middle school. The research of Waller (1977) and others documents the critical correlation of concrete operations and fluent reading and the inseparability of formal operations and mature reading comprehension. The findings of this investigation more specifically describe some of the student behaviors that reveal those cognitive operations. These results suggest that students not only use

strategies to literally comprehend passages but also use strategies to act on that comprehension, to "solve problems" as well. "Literally bound responses," and "perplexed responses," in this context, demonstrate difficulties in mature reading comprehension. All fifteen students in the original sample group could read and understand the problem solving tasks--that is, to literally comprehend the passage. They could define the problem and explain what they were asked to do, even if they could not generate a solution. Their difficulties lay in the problem solving domain; that is, in inferential comprehension. As formal operations and mature reading comprehension are so inextricably linked, these findings suggest that more emphasis be given to teaching and encouraging problem solving strategies. If teachers wish to improve "inferential comprehension," they may need to simultaneously provide enrichment in problem solving. Activities such as brainteasers, syllogisms, and verbal analogies provide excellent means toward this end. Setting aside even ten minutes each day for thinking and discussing verbal problems may thus prove invaluable.

These results also suggest teaching procedures for enriching reading and thinking development. The small group discussion format used by researchers in gathering data was an especially productive means to facilitate problem solving. Students reinforced each other in probing for solutions. Those students who were initially "perplexed" by the problems benefitted from hearing the comments of other students. Over the course of the three months of the investigation, all four researchers noted numerous incidents of students learning new ways to solve problems. More importantly, perhaps, all fifteen students seemed to especially enjoy these problem solving sessions. Some students even began to bring their own problems for discussion and to ask for extra problems to do on their own time. Differences in strategy usage on oral and written protocols suggest that using both formats may be helpful in encouraging thinking. It seems likely that while discussion encourages interaction and shared problem solving, written exercises encourage introspection and individual creativity. Both dimensions may be necessary to developing productive thinking abilities.

Finally, the results of the study demonstrate the potential of modified protocol analysis procedures for generating descriptive insights into some of the ways students think and for doing so in a naturalistic manner. By analyzing only those types of responses readily available to classroom teachers, this study provides a set of descriptors teachers can use to informally diagnose students' levels of concrete and formal operation. Teachers can observe indicators of strategy usage and/or perplexion and literally boundedness as they occur naturally and plan appropriate reading and thinking enrichment. By using similar verbalization procedures, other researchers may well discover additional insights into the way early adolescents think. In so doing, teachers may better understand their students and further the effectiveness of middle school instruction.

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Appendix A

Problem Solving Strategies - Definitions for Analysis of Protocols

In the first phase of our reading and thinking research study with fifth and sixth grade students, we identified the following problem solving strategies:

Visualization - students create mental pictures of solutions; students "see" solutions without manipulating materials, trying out ideas, or further analyzing input

examples:

"I just pictured the answer in my head."
"I just kind of drew a mental picture."
"I just looked at them and said 'This will work.'"

Experimentation - students test hypotheses and try out possible solutions: students attempt various solutions and see which "fit."

examples:

"I knew the bottom one had to come to the top so I just kept moving others around."
"It's that letter plus two, then three . . . no! Wait! That won't work."
"There might be more, some bigger, yes, there is another and another."

Abstraction - students form generalizations, synthesize concepts, eliminate factors that do not apply; students identify essential concepts and eliminate extraneous information

examples:

"It's a matter of deciding what matters in the problem and what doesn't."
"What's really important is the sequence."
"What you have to do is keep two together."

Extension - students apply strategies from previously solved problems or other circumstances to new problems; students rely on their own personal experience

examples:

"This is just like a problem I heard on the radio."
"This is similar to shooting pool. I've seen how this works."
"If that problem with four sides is a trapezoid, this one with five sides is a pentagon."

In analyzing a wider sample of protocols, we found these additional approaches to solving problems:

Perplexed responses - students "don't know" the solution, find the problem "too difficult" or "confusing"; they do not attempt a solution

Literally bound responses - students focus on one or two details of the problem and cannot consider the problem as a whole (not seeing the forest for the trees); students "fixate" on one aspect of a problem which precludes inference

Attempted strategies - students attempt to use one of the four primary strategies but cannot use them successfully:

attempted visualization
attempted experimentation
attempted abstraction
attempted extension

Appendix B

Sources of Problem Solving Tasks

Interview = Sund, Robert. Piaget for Educators. Columbus, Ohio: Charles E. Merrill Publishing Co., 1976.

Thinklab = Thinklab. Chicago: Science Research Associates, 1974.

Underlined titles = Harnadek, Anita. Basic Thinking Skills. Troy, Michigan: Midwest Publications, 1977.

*Denotes problems selected for detailed analysis.

Concrete - Operational Tasks

Seriation
interview p. 136

Ordering
interview p. 137
Figure Patterns

Correspondence
interview p. 137
concrete test items 8, 12, 17

Horizontal and Vertical Orientation
interview p. 138
concrete test items 6

Reversibility
interview p. 139

Reverse Seriation
interview p. 139

Classification - Ascending and Decending Hierarchy
interview p. 139

Conservation:

Area
interview p. 140
concrete test items 5, 24

Volume
interview p. 141
concrete test items 7, 9
Conservation 12

Substance
interview p. 141
concrete test items 3

Length (distance)
concrete test items 1, 22, 28
Conservation 13

Formal - Operational Tasks

Complex verbal problems
Thinklab 13, 14, 16, 17*

Proportional reasoning
*interview p. 144

Syllogistic thinking
*interview p. 147
logical test items 8, 9, 10

Verbal deductive reasoning
interview p. 146
Cause and Effect
*Inferences A

Hypothetical reasoning
*interview p. 148
logical test items 1, 2, 3, 4, 5

Proportional reasoning
logical test items 6, 7, 13, 14, 15

Memory logical reasoning
*interview p. 149

Creating theories
*Patterns

Verbal analogies
logical test items 16-21
*Reasoning by Analogy
Analogies C

Concrete - Operational Tasks

Part-Whole Relationships
interview p. 141
Conservation 14

Number
interview p. 142

Physical Causality
interview p. 142

Class Inclusion
interview p. 143
concrete test items 2, 13, 21

Spatial Relations
concrete test items 4, 10
Thinklab 1,2,4,5,7,8,9,10

Image Patterns
Thinklab 30,31,32,33,34,35,36

Formal - Operational Tasks

Logical analysis (absorbing multiple data, testing hypotheses and planning a set of operations)
Thinklab *91,92,95,96,97,98,99,100

Creative insight (developing abstract relationships from given data)
Thinklab *21,22,23,24,28,29

Please help us with our "reading and thinking research study" by reading the problems below and writing out your answers. Whether you solve the problem or not, please try very hard to explain exactly what you are thinking. In other words, we are more interested in HOW YOU TRY TO SOLVE THE PROBLEM than in "correct" solutions.

Thank you very much.

Problem #1

There's a ping-pong ball in a hole. The hole is just a little bit bigger around than the ball. It's longer than your arm is. Or anyone else's arm. There are no sticks around. What can you do to get the ball out of the hole?

Problem #2

If you drop a paper match, it will land flat on its side. What can you do so when you drop it, it will land balanced on an edge?

Problem #3

At a checker tournament, there were sixty-four players. It was an elimination tournament. When a player lost, that player was out of the running. How many games were played before there was a champion?

Problem #4

Once upon a time a party of eleven travelers swarmed down on a little country inn whose harassed host had only ten beds in which to dispose them. However, being an ingenious fellow, he met the situation bravely by putting two guests in the first bed, assuring the second of the two that he would have a bed for him in a short while. Then he put the third guest in the second bed, the fourth guest in the third bed, guest number five into bed number four, and so on until he put guest number ten into bed number nine. This accordingly left bed number ten empty and he called the eleventh man, who was still occupying half of the first bed, to come and take it. What is the fallacy in this story? (Thinklab, S.R.A., 1974, number 97)

Problem #5

At a meeting of the television news staff, the weather reporter was told that her material was too dull. That night she made up for it.

"Good evening. Today's weather, as you have probably noticed, is different from yesterday's. If the weather is the same tomorrow as it was yesterday, the day after tomorrow will have the same weather as the day before yesterday. But if the weather tomorrow is the same as today, the day after tomorrow will have the same weather as yesterday. As you know, it's raining today, and it rained on the day before yesterday."

Was it raining or clear yesterday? (Rubin, Teaching Elementary Language Arts, Holt, Rinehart, and Winston, 1975, p. 100).